Endoprosthetic replacement of the distal humerus following resection of bone tumours

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Between 1988 and 2006, 18 patients had a custom-made endoprosthetic replacement of the distal humerus for bone tumours at our institution. There were 11 primary malignant neoplasms, six secondary deposits, and one benign aggressive tumour. The mean follow-up was for 4.4 years (1 to 18.2). Complications occurred in nine patients and included aseptic loosening in three (16.6%), local recurrence in two (11%), infection in two (11%), neuropathia of the radial nerve in one (5.5%) and a peri-prosthetic fracture in one (5.5%). Excision was inadequate in four patients (22%), all of which developed local recurrence and/or metastases. There were seven deaths from the primary disease after a mean of 2.3 years (1 to 5), one of whom had an above-elbow amputation for local recurrence seven months before death. The remaining six had satisfactory elbow function at their last follow-up. The 11 living patients were evaluated using the Musculoskeletal Tumour Society and Toronto Extremity Salvage scoring systems. The mean scores achieved were 76% (67% to 87%) and 73% (59% to 79%), respectively. Overall, 17 of 18 patients had significant improvement in the degree of their pain following operation.

Custom-made endoprosthetic reconstruction of the elbow for bone tumours is a viable treatment in carefully selected patients. It maintains satisfactory function and provides good pain relief.

The elbow is a very unusual site for both benign and malignant bone neoplasms. Primary tumours affecting the distal humerus represent only 1% of all primary bone lesions.1,2 A published mini-series has shown lymphoma to be the most common malignant tumour arising around the elbow, and osteoid osteoma the most frequent benign tumour.1 Since the introduction of limb-salvage procedures and modern adjuvant therapies, reconstruction of the elbow after resection of bone tumours in the distal humerus has become a viable alternative to amputation, taking into consideration the resultant functional loss and cosmetic deformity associated with the latter procedure. However, the options for reconstruction are limited, technically challenging, and have an unpredictable outcome.

Allograft reconstruction, arthrodesis, hemiarthroplasty and excision arthroplasty have all been performed for non-malignant conditions around the elbow, but high rates of complication, instability and poor functional outcomes have been described.1-3 Such problems are more common after resection of a tumour, as removal of some or all of the surrounding ligaments and soft tissues may be necessary to allow an adequate margin of resection.

Endoprosthetic replacement for osteoarthritis (OA), rheumatoid arthritis (RA) and complicated fractures has been associated with satisfactory outcomes.4-11 This procedure has also been recommended for tumours of the distal humerus.2,12-14

We present our experience of reconstruction with a custom-made elbow endoprosthesis (Stanmore Implants Worldwide Ltd; Centre for Biomedical Engineering, Stanmore, United Kingdom) after resection of bone tumours of the distal humerus.

Patients and Methods
Between 1988 and 2006, 18 patients had a custom-made endoprosthetic replacement of the distal humerus performed by the two senior oncological surgeons (SRC, TWRB) at our institution. We obtained clinical data from the case notes, hospital databases, imaging studies, clinic reviews and patient questionnaires. There were 11 males and seven females, with a mean age of 48.2 years (5 to 87). The mean overall follow-up was 4.4 years (1 to 18.2) for all patients, 5.8 years (1 to 18.2) for the patients who were alive.
at the time of this review, and 2.3 years (1 to 5) for the seven who had died. Patients were referred to our regional tumour service and managed by a multidisciplinary team. Pre-operative imaging for staging included plain radiographs, bone scans, CT and MRI. Needle and/or open biopsies were obtained to confirm the diagnosis in all cases. Adjuvant chemo- and radiotherapy were administered when recommended by an oncologist. Endoprosthetic replacement was not considered in the presence of extensive soft-tissue disease or invasion of the neurovascular bundle. There were 11 patients with primary malignant tumours, six had secondary tumours, and one an aggressive giant cell tumour. The patients alive at the time of this review were assessed using the Musculoskeletal Tumour Society (MSTS) and the Toronto Extremity Salvage Score (TESS) systems.

The MSTS score assigns numerical values (0 to 5) for each of six categories: pain, function, emotional acceptance, hand positioning, dexterity and lifting ability. A numerical score and a percentage rating is calculated to allow for comparison of results. The TESS evaluates physical disability on the basis of the patient’s reports of their function. It comprises 32 questions for assessment of the activities of daily living, and was completed by 11 patients. Table I shows details of the patients’ diagnoses and outcomes, in order of the date of surgery.

**The prosthesis.** The prosthesis is a custom-made constrained hinged implant (Stanmore Implants Worldwide Ltd.). It is made using computer-assisted design and computer-assisted manufacturing technology (CAD-CAM) (Figs 1 and 2). It is made of cobalt-chrome and has humeral and ulnar stems connected by a metal pin, which passes through two high-density polyethylene bushes and is fastened with a C clip. The prosthesis is manufactured after determining the level of transection of the humerus on plain radiographs and/or other imaging. The humeral component has a hydroxyapatite (HA)-coated collar proximally, which has been shown to help reduce the incidence of loosening. Both stems are fluted to provide rotational stability.

**Surgical technique.** The procedure is performed through a standard posterior approach, after which a triceps flap is created and the ulnar nerve transposed anteriorly. Extra-articular resection of the tumour is then carried out while protecting the radial and posterior interosseous nerves. The components are then inserted into the ulna and humerus after preparation of the canal using tobramycin-impregnated cement. The prosthesis is then connected using the pin and bushings. The triceps muscle flap is re-attached and the wound closed. Routine mobilisation is allowed after operation, but active elbow extension is not allowed for three to four weeks. The patients are then followed up clinically and radiologically until the wound has healed, and then according to their primary diagnosis (Figs 3 and 4).
Results
The survival of the implant was 78% at a mean of 4.4 years (1 to 18.2).

Complications. Table I indicates that nine patients had one or more complications, with two patients having two. Of these patients, seven had a second procedure.

Aseptic loosening occurred in three patients. Two were of the humeral component and one was of the ulnar. A new prosthesis was inserted in two of these patients, one at seven years and the other at 10.1 years. The third had the humeral component recemented and the high-density polyethylene bushes replaced at 18 months.

Local recurrence was seen in two patients at 10 months and 18 months respectively after operation. Both patients had incomplete or marginal excisions. The first patient had excision of the recurrent lesion followed by radiotherapy, and is currently disease-free. The second had an above-elbow amputation, but died seven months later.

New metastases were seen in the lungs in two patients. One died at 12 months, the other at 23 months. Both had incomplete or marginal excisions.

Post-operative infections occurred in two patients. The first had a superficial infection which was successfully treated by wound debridement and antibiotics at three months. The second patient had a deep infection and underwent two revision procedures at 18 months and eight years respectively after the original procedure.

One patient had a neuropraxia of the radial nerve, which resolved completely by six months after operation.

Revision procedures were required in four patients at a mean of 4.6 years (1.5 to 7.2). The indications for revision were aseptic loosening and infection, as described above. In one patient, a humeral peri-prosthetic fracture occurred following a fall at three years. This was treated by revision to a longer humeral stem.

Seven patients died of their disease after a mean of 2.3 years (1 to 5). Four of 18 patients had an incomplete or marginal excision and all developed local recurrence or metastatic disease. Of these patients, three died at a mean of 20 months, but the fourth, although treated for local recurrence, is currently disease-free. The initial diagnosis in four of the seven patients was a metastatic tumour, whereas the remainder had a primary neoplasm.

All patients initially presented with mild to severe pain in the elbow. Of the 18, 17 had marked improvement in their pain compared to pre-operative levels at their last follow-up, and only two of the 11 living patients used analgesics regularly at night.

Functional outcome. The mean MSTS score was 76% (67% to 87%) (Tables I and II), with the following breakdown: pain (82% (60% to 100%)), function (70% (60% to 100%)), emotional acceptance (78% (60% to 100%)), hand positioning (74% (60% to 100%)), dexterity (92% (60% to 100%)) and lifting ability (58% (20% to 100%)). The mean TESS score was 73% (59% to 79%) (Table I).

All the patients were able to brush their hair and teeth, drink from a cup, lock and unlock doors, and pick up small objects with the operated arm. However, they had significant limitation in their ability to lift larger or heavier objects, such as shopping bags. Only one patient found writing difficult.

Discussion
Neoplastic disease affecting the distal humerus and elbow is rare. This series is the largest describing reconstruction of the elbow using custom-made constrained prostheses for bone tumours. Various methods of reconstruction have
been reported in the literature, and these are summarised below, with their outcomes.

Dean et al. described the use of allografts for elbow reconstruction in 23 patients with indications including massive bone loss after trauma in 20, revision of a failed elbow arthroplasty in two, and following resection of a tumour in one. Complications occurred in 16 patients (69.5%), including nonunion (five patients, 21.7%), instability (six patients, 26%), radial nerve palsy (four patients, 17.4%), deep infection (three patients, 13%), a poor range of movement (two patients, 8.7%), and resorption of the graft (one patient, 4.3%). The conclusion was that the operation was not recommended for routine use and was only viewed as a salvage procedure. It did not preclude subsequent elbow reconstruction.

Kimura et al. described a case of Ewing’s sarcoma of the elbow in an eight-year-old girl treated by hemiarthroplasty with a vascularised fibular graft. Four years postoperatively, she had excellent function, with an active range of movement of the elbow between 0˚ and 100˚.

Kulkarni et al. described ten patients with tumours involving the distal humerus treated by a constrained hinged prosthesis similar to the one used by us. Of eight patients with primary and two with secondary tumours, six were alive at the time of review at a mean follow-up of eight years. Complications occurred in four patients, with a further operation required in four. Of these patients, three developed aseptic loosening requiring revision. The mean TESS in this study was 73% (29% to 93%) of normal.

Sperling et al. described 13 patients with tumours involving the elbow treated by a version of the semi-constrained Coonrad prosthesis (Zimmer Corporation, Warsaw, Indiana). There were seven patients with primary and six with

Table II. Functional evaluation using the Musculoskeletal Tumour Society15 scoring system

<table>
<thead>
<tr>
<th>Function</th>
<th>Mean score</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>4.1</td>
<td>82</td>
</tr>
<tr>
<td>Function</td>
<td>3.5</td>
<td>70</td>
</tr>
<tr>
<td>Emotional acceptance</td>
<td>3.9</td>
<td>78</td>
</tr>
<tr>
<td>Hand positioning</td>
<td>3.7</td>
<td>74</td>
</tr>
<tr>
<td>Dexterity</td>
<td>4.6</td>
<td>92</td>
</tr>
<tr>
<td>Lifting ability</td>
<td>2.9</td>
<td>58</td>
</tr>
<tr>
<td>Overall score</td>
<td>22.7/30</td>
<td>76</td>
</tr>
</tbody>
</table>
secondary tumours. The mean follow-up was for 2.5 years. Complications occurred in six patients, five of whom required further surgery. After operation the pain scores decreased from a pre-operative mean of 3.6 to a mean of 2.0, on a scale with a maximum of 4.

Weber, Lin and Yasko\textsuperscript{19} described the use of segmental total elbow prostheses (Stryker Howmedica, Biomet Inc; Zimmer, Warsaw, Indiana) in 11 patients for malignant tumours, as part of a series of 11 distal and 12 total humeral replacements. The mean follow-up was 47 months (24 to 124) for the living patients and 37 months (1 to 42) for the deceased. The overall complication rate was divided into early (eight patients, 35\%) and late (seven patients, 30\%). Local recurrence occurred in 26\% of patients. The mean MSTS score for the patients who underwent elbow reconstruction was 83\% (80\% to 87\%).

Athwal et al\textsuperscript{14} described 20 patients who underwent total elbow arthroplasty for primary and secondary tumours involving the elbow. A standard linked semi-constrained Coonrad-Morrey prosthesis (Zimmer) was used in 19 patients and a custom-made prosthesis in one. The mean follow-up was for 30 months and five of the patients (25\%) were alive at the time of review. There were complications in 11 patients, including nonunion (two patients, 10\%), nerve injury (five patients, 25\%), local recurrence (five patients, 25\%), and peri-prosthetic fracture (two patients, 10\%). The revision rate was 20\%. The mean Mayo Elbow Performance Score\textsuperscript{20} improved from 22 to 75 points post-operatively.

In broad terms, the important considerations to take into account when performing reconstruction after resection of a tumour include the morbidity of the procedure, the incidence of complications, the functional demands of the patient and the durability of the reconstruction.

As shown above, our complication and re-operation rates are similar to those of other studies.\textsuperscript{2,12-14,19} The mean MSTS and TESS scores in our series were respectively 76\% (67\% to 87\%) and 73\% (59\% to 79\%) of normal in 11 patients at a mean follow-up of 5.8 years (1.2 to 18.2). This is encouraging when consideration is given to the initial diagnosis and to the anatomical distortion created at the elbow after resection of the tumour and a significant proportion of the surrounding soft tissues. Weber et al\textsuperscript{19} noted a slightly higher mean MSTS score of 83\% following elbow reconstruction for tumour, but this was in a smaller group with five living patients and a shorter follow-up (mean of 36 months). To our knowledge, no accounts of the MSTS scores following above-elbow amputation are available to make a comparison with functional results after resection of the tumour and reconstruction. However, limb salvage is generally preferred by patients if their survival is not compromised. It is also more cost effective.\textsuperscript{21}

The survival of the implant was 78\% at a mean of 4.4 years (1 to 18.2). The mean time to revision in the four patients mentioned earlier was 4.6 years (1.5 to 7.2). These figures compare favourably with those of other studies.\textsuperscript{2,12-14,19}

All four patients with inadequate excision developed local recurrence or metastases, with three dying at a mean of 20 months (12 to 25), suggesting that adequate resection significantly affects the outcome.

Limb salvage with endoprosthetic elbow replacement for distal humeral tumours is a major undertaking. Complete
excision of the tumour is extremely important and appears to have a bearing on long-term survival. Patients need to be counselled pre-operatively regarding the main complications, rates of re-operation, local recurrence and long-term survival.

Endoprosthetic reconstruction of the elbow at a specialist orthopaedic oncology centre with the facilities to access custom-made prostheses represents a viable option for treatment in carefully-selected patients. It provides good relief of pain and maintains satisfactory elbow function. It can be used for both primary and secondary tumours, and is associated with an acceptable complication rate when consideration is given to the nature of the diagnosis.

The authors would like to thank Dr. Paul Unwin PhD, General Manager of Stanmore Implants Worldwide Ltd for his contribution in preparing this paper.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References